



Electrical and Optical Properties of Copper Indium Gallium Telluride Films

C. Vinothini

Department of Physics,
D.K.M College for Women (Autonomous),
Vellore, Tamil Nadu, INDIA.

Abstract: Copper indium Gallium Telluride films were deposited for the first time by the pulse electro-deposition technique at room temperature and at a constant potential of -0.75 V(SCE). The films exhibited single phase. Optical band gap of the films is in the range of range $0.9-1.5$ eV for various duty cycles. Capacitance voltage measurements indicated the films to exhibit p-type behavior. Resistivity was calculated from the resistance values and it was observed that the resistivity increased from 6.0 ohm cm to 18.0 ohm cm with increase of indium content. . The band gap of the films obtained to be in the range 1.08 eV to 1.29 eV as the gallium concentration increased.

Keywords: Thin films, Solar cells, Pulse electrodeposits, 1-III-VI₂ semiconductors, and chalcopyrite.

I. INTRODUCTION

The quaternary semiconductor compound $\text{CuIn}_x\text{Ga}_{1-x}\text{Te}_2$ (CIGT) belongs to A^I B^{III} C^{VI} family which has received considerable attention because of their application in solar cells [1]. Their interest is due to the wide range of physical properties specially their band gap (range $0.9-1.5$ eV) and their type of conduction, which makes them potential candidates for photovoltaic applications [2,3]. Until now, a very few works have been carried out on CIGT thin films. In this work, the pulse plating technique has been employed for the first time to deposit CIGT films of different composition.

II. EXPERIMENTAL ANALYSIS

CIGT films were deposited on tin oxide coated glass substrates (5 ohms/sq) at a deposition potential of -0.75 V(SCE). The total deposition time was 60 min. The precursors used were Analar grade 0.25 M CuCl_2 , 100 mM TeO_2 and the concentration of GaCl_3 and InCl_3 was varied to get different composition of CIGT films. Thickness of the films estimated by Mitutoyo surface profilometer varied in the range of $350-700$ nm with increase of duty cycle. The films were characterized by Xpertanalytical x-ray diffraction unit with $\text{CuK}\alpha$ radiation. Optical measurements were recorded using an Hitachi UV-Vis-IR spectro- photometer was reported in earlier reports[4]. The electrical resistivity of the CIGT films of different composition was studied by providing Indium ohmic contacts (0.1 cm²) on top of the film surface and the resistance was measured between the top Indium contact and the bottom tin oxide coated substrate.

III. RESULT AND DISCUSSION

Resistivity was calculated from the resistance values and it was observed that the resistivity increased from 6.0 ohm cm to 18.0 ohm cm with increase of indium content. The value of the resistivity is lower than an earlier report [5], the low resistivity is due to decrease of resistivity with increasing Cu/(In+Ga) ratio. This is due to an increase in carrier concentration with increasing with Cu/In ratio. In our study the Cu/(In+Ga) ratio decreased from 1.10 to 1.01 as the indium content increased. Fig.1 shows the variation of resistivity with composition.

Fig. 2 shows the variation of mobility (μ) of CIGT films of different composition with increase of sulphur content.. The mobility was determined by using the general equation [6]. It is observed from the figure that the mobility decreases from 8.30 cm² V⁻¹s⁻¹ to 9.78 cm² V⁻¹s⁻¹ as the indium content increases. Fig.2 shows the variation of carrier concentration (N) with duty cycle, calculated using general equation. The carrier concentration is found to vary from 1.25×10^{17} cm⁻³ to 6.0×10^{16} cm⁻³ as the indium content increased. The value of mobility is higher than an earlier report and the carrier density values are comparable with the same report [7].

Fig.3 shows the transmission spectra of the CIGS films of different composition deposited at 50% duty cycle. The spectrum exhibits interference fringes and the value of the refractive index was estimated by the envelope method [5] as follows:

$$n = [N + (N^2 - n_s^2)^2]^{1/4} \quad 1$$

$$N = (n_s^2 + 1)/2 + 2 n_s (T_{\max} - T_{\min}) / T_{\max} T_{\min} \quad 2$$

where n_s is the refractive index of the substrate, $T_{\max}$ and $T_{\min}$ are the maximum and minimum transmittances at the same wavelength in the fitted envelope curve on a transmittance spectrum. The values of the refractive index calculated from the above equations increased from 3.39 – 3.31 with decrease of gallium content. The values of refractive index lie in between CIT and CGT values. The value of the absorption co-efficient (α) was calculated using the relation

$$\alpha = 1/d \ln \{ (n-1)(n-n_s)/(n+1)(n-n_s) \} [(T_{\max}/T_{\min})^2 + 1] / [(T_{\max}/T_{\min})^2 - 1] \quad 3$$

where 'd' is the thickness of the film and the other parameters have the usual meaning as given for equation 1. The band gap of the films obtained from $(\alpha h\nu)^2$ vs $h\nu$ plot increased from 1.08 eV to 1.29 eV as the gallium concentration increased (Fig.3,4). These values coincide with earlier band gap values of CuInGaSe_2 [6].

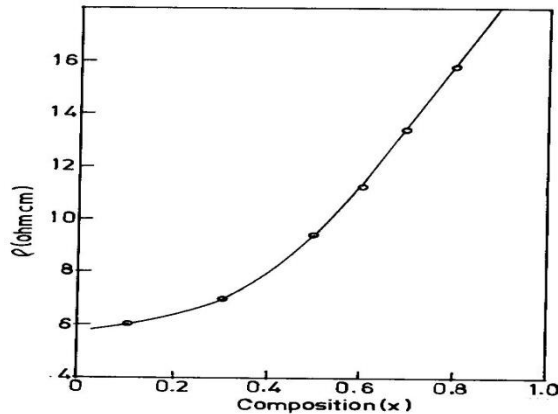


Fig. 1

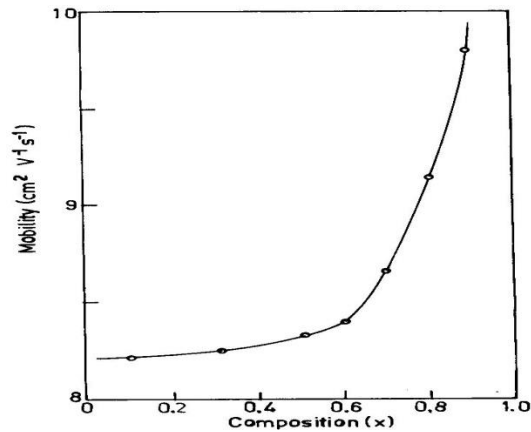


Fig. 2

Fig. 1 Variation of room temperature mobility with increase of In concentration of $\text{CuIn}_x\text{Ga}_{1-x}\text{Te}$ films deposited at 50 % duty cycle

Fig. 2 Variation of room temperature carrier density with increase of In concentration of $\text{CuIn}_x\text{Ga}_{1-x}\text{Te}$ films deposited at 50 % duty cycle.

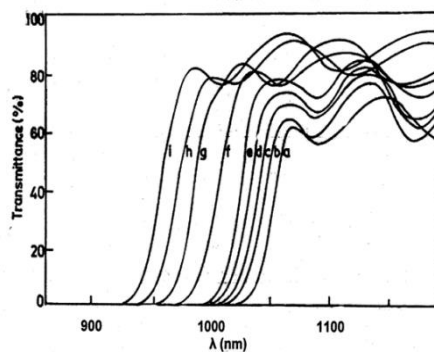


Fig. 3

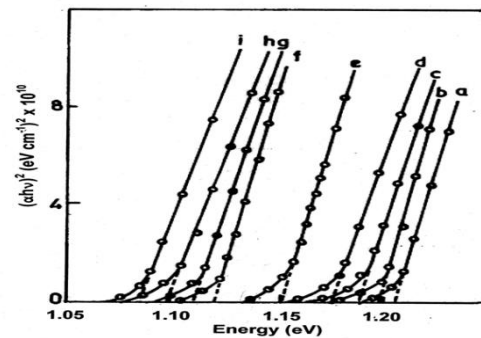


Fig. 4

Fig. 3 Transmission spectra of CIGT films of different composition deposited at 50 % duty cycle

Fig. 4 $(\alpha h\nu)^2$ vs $h\nu$ plot of $\text{CuIn}_x\text{Ga}_{1-x}\text{Te}$ films of different composition (a) $x = 0.1$ (b) $x = 0.2$ (c) $x = 0.3$ (d) $x = 0.4$ (e) $x = 0.5$ (f) $x = 0.6$

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